

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Conventional and Organic Farming — Does Organic Farming Benefit Plant Composition, Phenolic Diversity and Antioxidant Properties?

Alfredo Aires

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/61367>

Abstract

The growing demanding from consumers for healthier foods, produced using environmentally friendly farming practices has resulted in the rapid expansion of organic farming. There are numerous studies about the importance of organic farming but the majority of the results are sometimes contradictory, inconsistent and show no clear link between organic farming practices and enhancement of the nutritional quality of plant-derived foods. As such, ongoing research into the effects of organic farming and cultivation practices in comparison with intensive farming, is very important. The objective of this chapter is to discuss the most recent data and variation in the responses of plants to farming regimes in order to better understand the relationship between agricultural practices and high levels of valuable compounds (glucosinolates, phenolics, minerals, vitamins, antioxidants), as well as low levels of undesirable components such as nitrates, nitrites and microorganisms.

Keywords: Organic farming, conventional farming, nutrient diversity, phytochemicals, quality, safety

1. Introduction

Research studies continue to show that the desire of consumers to be able to purchase healthier fruits and vegetables, produced by a more sustainable and environmental friendly agricultural system, is increasing day-by-day. The majority of these studies attempt to show how safe and nutritious organic foods are for humans [1] and animals [2]. According to European regulations

[3] organic farming is defined as an overall system of farm management and food production that combines the best environmental practices, high levels of biodiversity, the preservation of natural resources, the application of high animal welfare standards and utilises production methods in line with the preference of consumers for products produced using natural substances and processes. The aim of an organic farming system is to provide to the consumer with fresh, tasty and natural food, while respecting natural systems and the environment. To achieve this, several principles and rules are followed in order to minimize human impact on the environment, while at the same time ensuring the agricultural system operates as naturally as possible [4]. Several different approaches are employed, but all of them are guided by strict rules [3] aimed at protecting the integrity of the environment, plants, animals and biodiversity.

A fundamental aim of organic farming is the provision of healthy, high quality plant and animal-derived foods. The concept of food quality can be defined in many different ways. Often, the quality of food is based on visual characters such as shape, size and colour, but can also be described as containing fewer pesticides, or more nutrients, or even containing specific functional properties due to elevated levels of phytochemicals [1, 5]. Thus, there is no one sole concept of quality. Nonetheless, countless studies of quality always refer to at least one or more of the following criteria: (i) food safety (absence of undesirable components like nitrites and pathogenic microorganisms); (ii) primary nutrients (minerals and vitamins, for example); (iii) secondary metabolites and phytochemicals that are closely associated with the beneficial health properties of plant and animal-derived foods; and (iv) observed health effects. However, research studies using these criteria vary widely, with investigative topics ranging from the taste of the food to how the food in question benefits health. Despite this diversity, the link between organic products and their nutritional, functional, and biological values is far from being fully understood. Therefore, in this chapter, we discuss recent advances in organic farming, particularly its differences from conventional farming, highlighting the differences in vitamins, minerals, phytochemicals, antioxidant activity and sensorial properties.

2. Factors and constraints affecting crop and plant-derived food composition

Growing crops in any part of the world is affected by many variables, including environmental, agronomical, social and economic factors, among others. These factors can affect not which particular type of agricultural system is employed, or which type of crop produced, but also and more importantly, the quality of the crop. Both conventional and organic farming systems are always heavily influenced by such factors. These factors can be grouped into 4 main types (Figure 1): a) socio-economic; b) pre-harvest; c) harvest; and d) post-harvest.

A recent study [6] showed that the choice between an organic or conventional farming system is primarily dependent on socio-economic factors, secondarily dependent on social aspects and then all of the remaining factors follow on. In fact, when farmers implement any production system or crop, their first question is: How profitable is it to produce? The answer will depend on the choices the farmer makes about what crops to grow, where to grow them, and

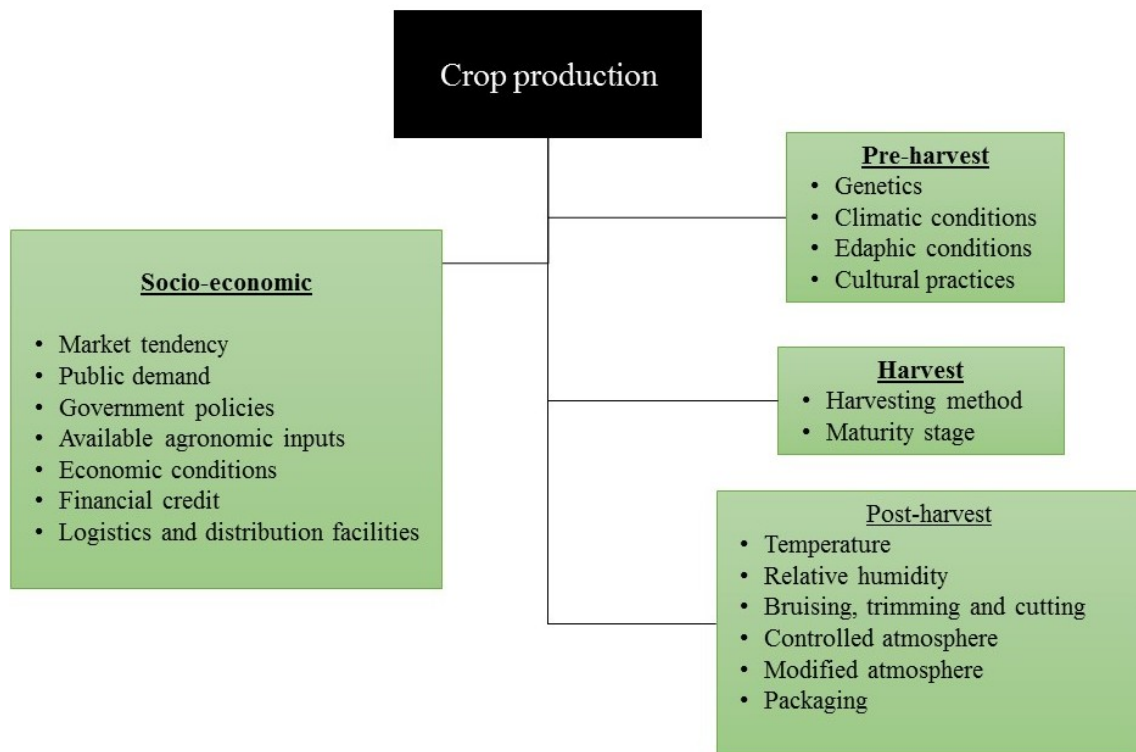


Figure 1. Constraint factors of any crop yield and production.

what technologies he uses. In addition, farmers tend to follow the system producing a higher financial income, lower financial risks, lower labour requirements, and if possible, the greatest pleasure [7]. The ability to obtain credit will also influence the choice of crops, farming systems and technologies [8]. The level of technical and scientific knowledge of production will also affect a farmer's propensity to choose a particular crop or production system [9, 10]. Moreover, the capital requirement for any crop development is always present, but can vary seasonally and is often far higher during harvesting than at other times during the production period. Any financial or labour constraint can negatively affect negatively the farmer's productivity and, therefore, income [11].

Another social aspect of decision to farm organically or conventionally is public demand [12]. If a farmer wants to succeed, then there must be a demand for their products, to generate an income, otherwise the farmer will switch to another, more profitable crop, whether it is organic or not.

Production is also affected by pre-harvest factors. In general, these factors include all physical factors, such as genetics, geology, soil and climatic conditions and cultural practices [13, 14, 15]. In other words, after a specific crop has been chosen, its success will depend on the outcome of the complex interaction between numerous elements such as the biology of the plant, interaction between plant and soil, crop management techniques, mineral and organic nutrition, chemical or biochemical treatments, and the watering regime employed, among other factors. Climatic parameters such temperature, humidity, altitude, rainfall and wind, are

all fundamental factors affecting the variation of plant and crop success [16, 17] and thus their nutritional quality as food. Temperatures can limit the growth of crops; water is a key factor in plant growth with different crops requiring water at different times; altitude primarily affects the average temperatures and consequently the type of farming; wind can have a destructive effect on crops physically, as well as increasing the dryness of soils, reducing moisture and increasing the potential for soil erosion. The soil type will influence crop cultivation because different crops prefer different soils, e.g., clay soils with their high levels of water retention are widely used to produce rice, as rice requires a lot of water to grow successfully [18, 19], whilst sandy soils are more suited to roots, tubers and vegetables, due to their need for better drainage, which is a requirement for good development of their roots [20]. Thus, selecting the right crop for the given specific conditions is fundamental to increasing yield and quality.

Another set of factors are related to the harvest period. It is widely accepted that stage of maturity at harvest can have a critical influence on the nutritional content of the crop. Zaro et al. [21], observed marked changes in the level of bioactive compounds present (anthocyanins, carotenoids, ascorbic acid, phenolics) and in antioxidant activity of purple eggplants at the fruiting stage. They found a decrease of such compounds and beneficial properties when plants were harvested at earlier stages (I and II). The same tendency was recently observed [22] in carrots, where a relatively high amount of falcarindiol, an important antioxidant compound, was present during very early harvest (i.e. 103 to 104 days after sowing) compared with a later harvest (i.e. 117 to 118 days after sowing). The same trend was also recently noted [23] for anthocyanin content in blueberries when harvested earlier, but not when harvested at full maturity. Thus, correct choice of harvesting time is crucial in preserving the quality of fresh produce during storage. This way, it is possible to provide the consumer with high quality fresh food products.

After harvesting, several factors (identified here as post-harvest factors) can interfere with the quality of fruit and vegetables. Among them are temperature regime of storage, relative humidity of storage, type of atmosphere used if any, and packaging [24, 25]. Temperature management during shelf-life is one of the most important means of preserving the quality of fresh roots, fruits and vegetables. After harvest, any delay in cooling, or choosing the wrong temperature regime, can result in losses in nutritional quality, flavour, taste and saleability. Tano et al. [26], found that the quality of mushrooms, tomatoes and cabbages stored under a fluctuating temperature regime was severely affected by extensive browning, loss of firmness, increased weight loss, increased level of ethanol in plant tissues, and fungal infections due to physiological damage and excessive condensation, when compared with products stored at a constant temperature. Similar observations were recently made [27] for mandarins, when low storage temperatures (2, 5 and 8 °C) resulted in a loss of orange peel colour, volatile compounds, and flavour. Thus, storage temperature is a fundamental factor affecting nutrients, colour and flavour [27]. In addition, particular attention should be paid post-harvest procedures such as cleaning, bruising, trimming and cutting, which may also affect the quality of products if they are conducted in inappropriate conditions or improperly performed [28]. Thus, the quality and stability of plant-derived food products will be strongly dependent on

the interaction of several different factors and, therefore, an understanding of the physiological and biochemical process in plants and foods during the period of shelf-life, is crucial to maximising their nutritional quality and bioactive composition, and thereby their properties beneficial to health.

3. Conventional versus organic

Organic farming has increased in popularity in recent decades due to the public's perception that health problems may arise from the consumption of plant-derived foods produced under intensive farming practices. This growing concern lead to a considerable number of studies into the effect of organic production on nutrients (mineral, vitamins) and phytochemicals such as polyphenols, antioxidant vitamins (A, C, E), glucosinolates, carotenoids and isoflavones, among others. Although a large number of studies about the differences between plants produced under conventional and organic farming systems is now available, most of the studies present contradictory facts, inconsistent results and the differences are often reported as negligible. Consequently, it is important to study the variation in nutritional quality and safety of plant-derived food produced under both organic and conventional farming methods. In the following paragraphs we discuss recent findings about the effect of the two different agricultural systems on the variation in nutrients and phytochemicals in plant-derived food, focusing on the major differences already discovered.

3.1. Variations in vitamin, mineral, amino-acid and nitrate content

The nutritional value of food is essentially a function of its vitamin and mineral content, particularly those related to important beneficial functions in animals and humans [29]. Essential minerals required in the human diet include, among others, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), sulphur (S), boron (B), chromium (Cr), cobalt (Co), copper (Cu), iodine (I), manganese (Mn), molybdenum (Mo), selenium (Se), tin (Sn), and zinc (Zn) [30, 31] and the essential vitamins include mainly A, B (all vitamins of the B complex), C, E and K [30]. Compared with conventional farming, organic production relies on sustainable management practices, which include crop rotations, cover cropping, nutrient recycling, integrated pest management, and use of organic fertilisation [32], among other practices. All these practices, according to the majority of consumers have indeed had a positive impact on food quality, enhancing the levels of beneficial minerals and vitamins [33]. However, from a scientific point of view, the question of whether organic plant-derived foods are more nutritious than conventional ones remains.

Conventional farming usually relies on massive doses of readily soluble forms of mineral fertilisers (mainly in N, P, K form), whilst organic farming relies on the incorporation of organic material into the soil, normally through the use of animal manure as fertiliser [34]. Composted manure is the most commonly used fertiliser in organic farming [35] and thus the general consumer perception is that organic foods are better because they are produced using natural and safe agronomical inputs [33], and thus they are more nutritious.

Throughout the past 15 years, several comparative studies have demonstrated significant differences in the content of vitamins, minerals and free amino-acids (Table 1). However, several authors claim that no major or significant differences are found in mineral and vitamin content in fruits and vegetables produced under organic or conventional farming systems, and several others report that for some specific nutrients, conventionally grown plant-derived foods usually contain higher average levels (Table 1).

Products tested	Nutrients analysed	Key-results	Reference
Lettuce, spinach, carrots, potato and cabbage	Iron, Mg, and P	Higher in organics	[36]
Chinese mustard, Chinese kale, lettuce, spinach	Vitamin C, β -carotene and riboflavin	Higher in organics	[37]
Wheat	Minerals (N, K, Mg, Ca, S, Fe,)	Similar in both	[38]
Red potatoes	Minerals (K, Mg, P, S and Cu)	Higher in organics	[39]
Wheat	Essential Amino acids	Lower in organics	[40]
Wheat	Minerals (P, K, Ca, Zn, Mo, Co)	Similar in both	[40]
Kiwi fruits	Minerals (N, P, K, S, B, Ca, Mg)	Higher in organics	[41]
Tomato	Vitamin C	Lower in organics	[42]
Broccoli	Vitamin C	Similar in both	[43]
Spinach	Nitrate	Lower in organics	[44]
Strawberry	Vitamin C	Similar content	[45]
Broadbean, bean, lettuce, pepper, watermelon.	Nitrates	Lower in organics	[46]
Acerola	Vitamin C and carotenoids	Higher in organics	[47]
Strawberries	Vitamin C and carotenoids	Similar in both	[47]
Cauliflower	Vitamin C	Higher in organics, but only when higher organic fertiliser levels were applied	[48]
Potatoes	Essential amino acids	Higher in organics	[49]
Strawberries	Ascorbic acid	Higher in organics	[50]
Cauliflower	Soluble solids, nitrates, P and K	Similar in both	[51]
Green pepper	Weight, firmness, thickness, N and P	Lower in organics	[52]
Tomatoes	Vitamin C	Higher in organics	[53]
Apple	Aromatic volatiles, organic acids and sugars	Higher in organics	[54]

Table 1. Differences in the content of nutrients in organic and conventional fruit and vegetables

Some research studies have claimed that organic amendments can have a positive effect on the content of antioxidant vitamins such as vitamin C [47], but others claims that the effect is negative [42], whilst others still, claim no significant difference [43, 45, 55]. Thus, there is a discrepancy in the results, and external factors such as crop variety, crop location, climate and growing conditions [56] can all exert an effect. Moreover, it is unlikely that mineral fertilisers or manure alone can affect the nutritional content of fruits and vegetables. Nonetheless, the majority of authors seems to agree that an organic production system is friendlier than an intensive or conventional farming system and the choice of organic system as an alternative to conventional practice can be justified by its lower environmental impact [57].

Another important issue related to the nutritional quality and safety of organic food is nitrate content, particularly in fresh vegetables. Nitrates are a natural consequence of the mechanism by which plants absorb the element nitrogen, in the form of NO_3^- , from fertilisers or organic material [58]. Although nitrate is an important component of plants, it has the potential to accumulate in tissues, particularly in green leafy vegetables [59] and thus, nitrate from fertilizers could accumulate in vegetables on a large scale. The danger of this, lies in the fact that nitrates can be reduced to nitrites, which can react with amines and amides to produce “N-nitroso” compounds, responsible for gastric cancer [60]. In order to maximize the health benefits from eating vegetables, measures should be taken to reduce levels of nitrates and nitrites [59]. This is particularly true in organic farming due to the large quantities of manure used as natural fertiliser, which is sometimes reported as having the potential to elevate levels of nitrates and nitrites up to, or above, maximum residue levels (MRLs), which is dangerous. However, some studies report that manure fertilisers have no significant effect on nitrate levels because organic products should always contain fewer nitrates than their counterparts produced by conventional methods, due to their lower concentration of nitrogen-based fertilisers [61, 62]. Furthermore, several other authors have reported that nitrate content is more closely related to genotype, soil conditions, growth conditions (i.e., nitrate uptake, nitrate reductase activity, and growth rate), storage and transport conditions, than to mineral or organic amendments [63]. More recently [64] it was shown that that nitrate accumulation in vegetables is more closely related to the quality of water and water accumulation in vegetable tissues. Thus, the results available until now from various different studies are sometimes contradictory and doubts still remain. Nonetheless, based on the fact that organic farming enhances specific nutrients and is less aggressive to the environment, it is more beneficial than conventional farming, which is seen as more aggressive to the environment, fauna and flora, and ultimately, to animals and humans.

3.2. Influence on bioactive compounds and functional properties of foods

3.2.1. Glucosinolates, phenolics, carotenoids and pigments

Recent scientific advances in plant-derived foods studies have mainly focused on the potential health effects of phytochemicals in plant foods. Phytochemicals, also known as bioactive compounds, are naturally occurring substances in plants, functioning mainly as secondary metabolites [65]. Their distribution in plants is considered to be the result of the natural

adaptation of plants to environmental stress, pathogen infection, insects and other pests [66]. According Harbone [66], phytochemicals can be divided into different classes: phenolics (e.g. phenolic acids, flavonoids, anthocyanin), terpenoids (e.g., carotenoids, xanthophylls and other pigments), alkaloids (e.g., indole compounds), and sulphur-containing compounds (e.g., glucosinolates). Table 2 gives a brief summary of phytochemicals commonly found in fruits and vegetables, and the potential health benefits associated with them. To date, studies have shown that phytochemicals can have a protective effect on human health (Table 2 and Table 3), including mopping-up free radicals, reduction of oxidative stress, inhibition of cell proliferation, induction of cell differentiation, inhibition of oncogene expression, suppression of gene expression in carcinogenic processes, modulation of detoxification enzymes, stimulation of the immune system, regulation of hormone metabolism, and antibacterial and antiviral effects [67]. Strong associations have been also found between disease risk reduction and consumption of foods with a high content of glucosinolates (anti-cancer), tocopherols (cardiovascular), phenolics and carotenoids (eye-health) [68].

Phytochemicals		Example of food sources	Proposed health benefits found in literature
Class	Example		
Phenolic acids	Gallic acid, caffeic acid,	Tea, kiwi fruit, strawberries, pineapple, coffee	Antioxidant and anti-inflammatory
Flavonols	Quercetin	Red and yellow onions, tea, wine, apples, cranberries, beans	Antioxidant, anti-inflammatory, enzyme inhibitor and immune modulation
Flavanols	Catechins	Chocolate, tea, grapes, wine, apples, cocoa, black-eyed peas	Antioxidant, anti-hypertensive, anti-inflammatory, anti-proliferative, anti-thrombogenic, and lipid lowering effects
Flavones	Apigenin	Chamomile, celery, parsley	Lowers high blood pressure, antioxidant and anti-inflammatory
Anthocyanins	Cyanindin	Blackberry, blueberries, red wine, strawberries	Improvement of vision, and neuroprotective effects
Isoflavones	Genistein	Soy, alfalfa sprouts, red clover, chickpeas other legumes	Reduction in blood pressure, antioxidant activity
Lignans	Secoisolariciresinol	Linseed, sunflower seeds, sesame seeds, pumpkin seeds	Improves glucose control, prevents pre-cancerous cellular changes, decreases the incidence of several chronic diseases
Stilbenes	Resveratrol	Grape skins and seeds, wine, nuts and peanuts	Antioxidant, anti-inflammatory, protects the body against nitric oxide, keeps the blood vessels optimally dilated

Phytochemicals		Example of food sources	Proposed health benefits found in literature
Class	Example		
Carotenoids	Lycopene, beta-carotene and other types of carotenes	Carrots, spinach, tomato and several other types of fruits and vegetables	Neutralisation of free radicals that cause cell damage
Monoterpenes	Limonene	Citrus oils, cherries, spearmint, garlic, maize, rosemary, basil	Antioxidant, anti-inflammatory, anti-cancer, helps with weight management (“fat cleanser”) and helps clear cholesterol
Diterpenes	Gingkolides	Gingko biloba	Protects neurons against Abeta1-42-induced synapse damage and cognitive loss
Triterpenes	Ginsenosides	Ginseng	Boosts the immune system and may lower blood sugar levels
Phytosterols	Sitosterol	Sunflower oil, avocados, rice bran, peanuts, soybeans	Inhibits 5-alpha reductase in prostate tissue
Alkaloids	Capsaicin	Chili pepper	Reduces the expression of proteins that control growth genes that cause malignant cells to grow
Glucosinolates, isothiocyanates	Sulforaphane, allyl-isothiocyanate, phenethyl-isothiocyanate,	Broccoli, mustard, cress, cabbages and all Cruciferae family plants	Neutralisation of free radicals that causes cell damage. Protection against some cancers
Indoles	Alliin, allicin	Onions, garlic, leeks	Antimicrobial agents and decreases LDL cholesterol

Table 2. Examples of some important phytochemicals commonly found in foods

<ul style="list-style-type: none">• antioxidant activity• neutralises free radicals and reduces oxidative stress• inhibition of cell proliferation• induction of cell differentiation• inhibition of oncogene expression• inhibition of tumour gene expression• induction of cell cycle arrest• induction of apoptosis• inhibition of signal transduction pathways	<ul style="list-style-type: none">• phase II enzyme• glutathione peroxidase (GPX)• catalase• superoxide dismutase (SOD)• enzyme inhibition• phase I enzyme (block activation of carcinogens)• cyclooxygenase-2 (COX-2)• inducible nitric oxide synthase (iNOS)• xanthine oxide	<ul style="list-style-type: none">• enhancement of immune functions and surveillance• anti-angiogenesis• inhibition of cell adhesion and invasion• inhibition of nitrosation and nitration• prevention of DNA binding• antibacterial and antiviral effects
--	--	---

- enzyme induction and enhancing detoxification

¹ Adapted from Liu and Finley [67].

Table 3. Proposed health protective mechanisms of dietary phytochemicals¹

Glucosinolates are sulphur-containing compounds mainly present in the Cruciferae family. When consumed, they are hydrolysed via myrosinase (EC 3.2.1.147, thioglucoside glucohydrolase) into isothiocyanates (ITCs) and other derivative products [69], that up-regulate genes associated with carcinogen detoxification cellular mechanisms [70]. Clinical studies have shown that the products of glucosinolate hydrolysis can reduce the incidence of certain forms of cancer [71].

Other compounds such as carotenoids lutein, β -carotene and tocopherols in addition to their role as vitamins, are also powerful antioxidants [72]. Tocopherols and carotenoids have been associated with the decrease of certain forms of cancer [73] and with a reduction in risk of cardiovascular diseases [74], whilst lutein protects against the development of cataracts and age-related macular degeneration [75], even if according Trumbo and Ellwood [76] there is no credible scientific evidence to support a health claim that lutein or zeaxanthin intake can reduce the risk of age-related macular degeneration or cataracts.

Phenolic compounds are a large group of secondary metabolites, categorised according to their chemical structure, into different classes, with phenolic acids, flavonoids, stilbenes and lignans being the most relevant ones [77]. They all have in common the presence of labile hydrogen able to neutralise or mop-up free radicals, and as such they are recognised as powerful antioxidants. Fruits and vegetables are the richest potential sources of these substances [78].

As mentioned above, the diversity of the chemical composition of plants, and thus by extension of phytochemicals is determined by a number of factors, including genotype, ontogeny, growth conditions, management practices and the environment. Thus, it might be expected that differences caused by organic vs. conventional growing practices may cause associated differences in phytochemical levels and diversity. Increasing organic food consumption is partially as a result of consumer perception that organic foods are healthier, but do organic foods actually contain more phytochemicals than conventional foods? Are the levels of phytochemicals in organic production relevant? Is the diversity of phytochemicals in foods affected by agronomical practices?

Table 4 summarises some of the results from different studies conducted over the last 15 years into the difference in phytochemical content in fruits and vegetables produced under organic and conventional farming practices. This is not an exhaustive list, but unsurprisingly several different conclusions are drawn. Recent studies [79, 80, 53] have indicated that organic produce contains higher concentrations of certain phytochemicals associated with health, than those produced under conventional farming systems. In addition, some studies [81, 82] reinforce this idea, stating that the abiotic and biotic stress induced by organic farming practices seems to overcome the variability among samples and consequently, the use of organic practices may

be a means of increasing the levels of phytochemicals. However, according a recent observation [83] there is little evidence for any differences in the health benefits of organic and conventional produce. The differences often found may in fact be due to cultivar genotype influence and climatic variation rather than agricultural practices. The same observations was made by Oh et al. [84] and Lv et al. [85].

Crops & products	Bioactive substances	Key-results	Reference
Apple	Polyphenols	Higher in organic production	[86]
Chinese cabbage	Flavonoids	Higher in organic production	[87]
Spinach	Flavonoids	Higher in organic production	[87]
Green pepper	Flavonoids	Higher in organic production	[87]
Pear	Polyphenols	Higher in organic production	[88]
Yellow plum	Quercetin	Lower in organic production	[89]
Apple	Anthocyanins	Higher in organic production	[90]
Tomato	Lycopene	Similar content in both systems	[91]
Broccoli	Total glucosinolates	Lower in organic production	[92]
Strawberry	Polyphenols	Similar content in both systems	[93]
Tomato	Carotenes	Higher in organic production	[94]
Tomato	Polyphenols	Lower in organic production	[95]
Blueberry	Polyphenols	Higher in organic production	[96]
Tomato	β -carotene	Higher in organic production	[42]
Tomato	Lycopene	Lower in organic production	[42]
Carrot	Carotenoids	Similar content in both systems	[97]
Egg-plant pulp	Phenolics	Similar content in both systems	[98]
Cauliflower	Glucosinolates	Similar content in both systems	[48]
Strawberry	Anthocyanins	Higher in organic production	[79]
Soybeans	Isoflavones	Lower in organic production	[99]
Broccoli and collard greens	Glucosinolates	Higher in organic production	[100]
Watercress	Glucosinolates	Lower in organic production	[100]
Broccoli	Glucosinolates	Lower in organic production	[80]
Tomato	Polyphenols and lycopene	Higher in organic production	[53]
Pepper	Higher	Lower in organic production	[101]
Broccoli	Polyphenols	Similar content in both systems	[102]
Broccoli	Glucosinolates	Higher in organic production	[102]

Table 4. Summary of studies comparing phytochemical contents in fruits and vegetables from organic and conventional production

These authors stated that the most important factor affecting the phytochemical composition of plants is the interaction between genotype, environment and agronomical practices. Therefore, it is crucial to select the optimal environment conditions, genotype and best agronomical practices, in order to maximise the levels of a components beneficial to health.

In order to accurately evaluate the differences between organic and conventional farming systems, all the factors affecting quality of produce must be controlled, which is a major limitation of some studies through their poor experimental design. So, an accurate evaluation of all these aspects should be made over a substantial period of time (more than one year at least) in order to assess the eventual changes related to the year, seasonal effect, genotype or agronomical practices employed. A multi-year sampling study to evaluate farming systems with the necessary consistency to draw valid conclusions, is a minimum requirement [103].

3.2.2. *Antioxidant activity*

Closely linked to phytochemical content is the variation in antioxidants. Antioxidants, by definition, are any substance that reduce or inhibit oxidation or other reactions caused by oxygen and peroxides and free radicals, and which protect the body from the deleterious effects of free radicals [104]. Well-known antioxidants includes enzymes, vitamins (C and E), carotenes, polyphenols and others capable of counteracting the damaging effects of oxidation. They are important, because to date, epidemiological studies have shown their preventive effect against several infectious processes such as cancer, and neurodegenerative and cardiovascular diseases [105, 106, 62, 81]. As with primary nutrients and phytochemicals, the effect of organic farming practices on the antioxidant properties of plant-derived foods is controversial. It is common to find an association between organic farming practices and an increase in antioxidant content, and the converse is also true (Table 5).

Wang [81] found that organic practices result in an increase antioxidant activity in blueberries (measured by the ORAC) due to the increase of phenolic acids and anthocyanin content when compared with a conventional system, whilst Garuso and Nardini [107], didn't find any substantial difference in antioxidant activity in wines produced under organic and conventional farming practices. Similar observations were made by Unal et al. [108] for Brassicacea vegetables. They didn't detect any significant difference in antioxidant activity in brassicas produced under organic and conventional practices. However, Stracke et al. [97], when comparing the organic and conventional cultivation of apples over three years, observed that organic apples presented on average 15% higher antioxidant content, as determined by FRAP, TEAC and ORAC than conventionally produced fruits, but these authors also observed that inter-annual climatic variations were more critical to the antioxidant capacity than the type of farming. Despite these inconsistencies, the majority of authors seem to agree that the type of farming system may affect the phytochemical composition and thus by extension the amount of antioxidant activity. Since organic farming does not provide as much nitrogen as conventional fertilizers [56], as well as causing more stress to the plants (Straus et al., 2012)[109] than conventional farming, it has the potential to influence the synthesis of antioxidants, increasing their levels and thus increasing antioxidant activity, as recently reported [110]. Therefore, at least theoretically, it can be concluded that organic farming has a tendency to produce foods with more nutritional value, based on their enhanced antioxidant content and activity.

Crops & products	Antioxidant activity in organic compared to conventional counterpart	Reference
Blueberries	Higher in organics	[81]
Apples	Similar in both	[111]
Fruits and vegetables	Similar in both and no consistent trends were found	[112]
Tomato	Higher in organic	[113]
Grapes and wines	Higher in organics	[114]
Lettuce	Similar in both	[115]
Tomato	Higher in organics	[110]
Tomato	Higher in organics	[116]
Brassicas	Lower in organics	[108]
Oranges	Similar in both	[117]

Table 5. Some examples of studies comparing antioxidant activity of fruits and vegetables produced under organic and conventional farming practices

3.3. Consumers' sensory expectations and preferences related to variability of antioxidant activity and phytochemical content of organic foods

There is common belief that organic food is healthier and safer than conventional food. According to the vast amount of literature already published, some of which is reported in this chapter, organic food is free of chemical residues, contain fewer nitrates and more antioxidants. In respect of product quality, surveys in the last 10 years [118, 119, 120, 121, 122, 123] indicate that consumers consider organic foods to be more beneficial for human health than their conventional counterparts, even if those studies often assume a lack of knowledge on behalf of the consumers of the aims and production practices of organic farming. Moreover, consumers often buy organic foods based on an emotional view, such as a desire to preserve traditional products and processes [124]. According to a survey conducted in Turkey in 2012 [120] consumers indicated 4 main reasons to buy organic foods: they are healthier, they have higher quality, the price is normally acceptable, and the food is microbiologically safe. As Monk et al. reported in 2012 [125], for the majority of consumers, the idea of enhanced nutrition, being free from chemicals, and a better taste, are the major advantages of organic foods. Consumers often think that organic food is better because it tastes better, but apart from physical and sensorial qualities, the understanding of nutritional quality by consumers seems to be a question of the ability to find credible information [118], which they often can't. A recent survey [126] showed that 78% of consumers when questioned about the quality of labelling information, responded that they didn't believe that all food labelled 'organic' was, in fact, organic, and neither did they totally believe in their healthier effects. Often, consumers purchased organic food due to personal morals or beliefs such as: 'I feel obliged to buy organic food to protect my health' and 'I feel obliged to buy organic food to protect the health of my family' [126]. The same authors observed that consumers repeatedly reported that they

experience difficulty in getting more knowledge about a product's properties, certification bodies, and labels etc... Nonetheless, nowadays consumers tend to be more conscious and more aware about the positive effects of organic foods on health and the environment [127], and as a result are buying more organic foods.

4. Conclusions

Since the 1980s, organic farming has been increasing due to growing demand from consumers for high quality foods, with lower pesticide residues, less synthetic fertilisers and produced using environmentally friendly practices. Presumably, animal and plant derived foods have fewer chemical residues and veterinary drugs in them when compared with conventional ones. The growing perception from consumers that organic foods are healthier and safer, has to the rapid growth of this type of production seen over the last 20 years. Although the beneficial properties of these foods for human health have not been unequivocally proven, the accumulation of nutritional metabolites in organic cultivation has been well documented. Recent studies have shown that organic foods are, from a nutritional point of view, at least similar to conventional ones, if not slightly better. Also, recent epidemiological studies advocate that under organic farming practices, plants can accumulate nutrients and phytochemicals, enhancing their biological value and thus increasing the nutritional quality of foods. Moreover, the growing evidence of lower pesticide exposure to consumers of organic foods, is one of the main reasons for converting to organic farming. Although more and more well-documented studies are still required to improve our understanding of which factors contribute to differences between organic and conventional farming practices, the most recent findings provide evidence-based knowledge that organic farming is a sustainable way of producing healthier and safer plant-derived foods.

Acknowledgements

The author acknowledges the financial support provided by the Portuguese Foundation for Science and Technology (FCT) (Alfredo Aires-SFRH/BPD/65029/2009) under the project UID/AGR/04033/2013.

Author details

Alfredo Aires

Address all correspondence to: alfredoa@utad.pt

Centre for the Research and Technology of Agro-Environment and Biological Sciences (CITAB), Universidade de Trás-os-Montes e Alto Douro, UTAD, Quinta de Prados, Portugal

References

- [1] Huber M, Rembiałkowska E, Średnicka D, Bügel S, van de Vijver LPL. Organic food and impact on human health: Assessing the status quo and prospects of research. *NJAS - Wageningen Journal of Life Sciences*. 2011;58:103-109.<http://dx.doi.org/10.1016/j.njas.2011.01.004>
- [2] Velimirov A, Huber M, Lauridsen C, Rembiałkowska E, Seidel K, Bügel S. Feeding trials in organic food quality and health research. *Journal of the Science of Food and Agriculture*. 2010;90:175-182. <http://dx.doi.org/10.1002/jsfa.3805>
- [3] 189/1 RENEJotEUL. Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing EN Official Journal of the European Union L 189/1. 2007. <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0834&from=EN>
- [4] IFOAM. Definition of Organic Agriculture. 2009, <http://www.ifoam.bio/en/organic-landmarks/definition-organic-agriculture>
- [5] Renaud ENC, Bueren ETLv, Myers JR, Paulo MJo, Eeuwijk FAv, Zhu N, et al. Variation in Broccoli Cultivar Phytochemical Content under Organic and Conventional Management Systems: Implications in Breeding for Nutrition. *Plos One*. 2014. <http://dx.doi.org/10.1371/journal.pone.0095683>
- [6] Bowman MS, Zilberman D. Economic Factors Affecting Diversified Farming Systems. *Ecology and Society*. 2013;18:33. <http://dx.doi.org/10.5751/ES-05574-180133>
- [7] Stoorvogel JJ, Antle JM, Crissman CC. Trade-off analysis in the Northern Andes to study the dynamics in agricultural land use. *Journal of Environmental Management*. 2004;72:23-33.<http://dx.doi.org/10.1016/j.jenvman.2004.03.012>
- [8] Knowler D, Bradshaw B. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy*. 2007;32:25-48.<http://dx.doi.org/10.1016/j.foodpol.2006.01.003>
- [9] Chavas J-P, Kim K. Economies of diversification: A generalization and decomposition of economies of scope. *International Journal of Production Economics*. 2010;126:229-235.<http://dx.doi.org/10.1016/j.ijpe.2010.03.010>
- [10] Sautter JA, Czap NV, Kruse C, Lynne GD. Farmers' Decisions Regarding Carbon Sequestration: A Metaeconomic View. *Society & Natural Resources*. 2010;24:133-147.[10.1080/08941920903012502](http://dx.doi.org/10.1080/08941920903012502)
- [11] Bosi S, Magris F. Endogenous business cycles: Capital-labor substitution and liquidity constraint. *Journal of Economic Dynamics and Control*. 2002;26:1901-1926. [http://dx.doi.org/10.1016/S0165-1889\(01\)00013-6](http://dx.doi.org/10.1016/S0165-1889(01)00013-6)

- [12] Smith EG, Jill Clapperton M, Blackshaw RE. Profitability and risk of organic production systems in the northern Great Plains. *Renewable Agriculture and Food Systems*. 2004;19:152-158,
- [13] Tiwari U, Cummins E. Factors Influencing β -Glucan Levels and Molecular Weight in Cereal-Based Products. *Cereal Chemistry Journal*. 2009;86:290-301.10.1094/CCHEM-86-3-0290
- [14] Søltoft M, Nielsen J, Holst Laursen K, Husted S, Halekoh U, Knuthsen P. Effects of Organic and Conventional Growth Systems on the Content of Flavonoids in Onions and Phenolic Acids in Carrots and Potatoes. *Journal of Agricultural and Food Chemistry*. 2010;58:10323-10329.10.1021/jf101091c
- [15] Tiwari U, Cummins E. Factors influencing levels of phytochemicals in selected fruit and vegetables during pre- and post-harvest food processing operations. *Food Research International*. 2013;50:497-506.<http://dx.doi.org/10.1016/j.foodres.2011.09.007>
- [16] Krishnan P, Ramakrishnan B, Reddy KR, Reddy VR. Chapter three - High-Temperature Effects on Rice Growth, Yield, and Grain Quality. In: Donald LS, editor. *Advances in Agronomy*. Volume 111: Academic Press; 2011. p. 87-206.
- [17] Oloyede FM, Adebooye OC, Obuotor EM. Planting date and fertilizer affect antioxidants in pumpkin fruit. *Scientia Horticulturae*. 2014;168:46-50.<http://dx.doi.org/10.1016/j.scienta.2014.01.012>
- [18] Bhattacharyya R, Prakash V, Kundu S, Srivastva AK, Gupta HS. Soil aggregation and organic matter in a sandy clay loam soil of the Indian Himalayas under different tillage and crop regimes. *Agriculture, Ecosystems & Environment*. 2009;132:126-134.<http://dx.doi.org/10.1016/j.agee.2009.03.007>
- [19] Mekuria W, Getnet K, Noble A, Hoanh CT, McCartney M, Langan S. Economic valuation of organic and clay-based soil amendments in small-scale agriculture in Lao PDR. *Field Crops Research*. 2013;149:379-389.<http://dx.doi.org/10.1016/j.fcr.2013.05.026>
- [20] Zotarelli L, Scholberg JM, Dukes MD, Muñoz-Carpena R, Icerman J. Tomato yield, biomass accumulation, root distribution and irrigation water use efficiency on a sandy soil, as affected by nitrogen rate and irrigation scheduling. *Agricultural Water Management*. 2009;96:23-34.<http://dx.doi.org/10.1016/j.agwat.2008.06.007>
- [21] Zaro MJ, Keunchkarian S, Chaves AR, Vicente AR, Concellón A. Changes in bioactive compounds and response to postharvest storage conditions in purple eggplants as affected by fruit developmental stage. *Postharvest Biology and Technology*. 2014;96:110-117.<http://dx.doi.org/10.1016/j.postharvbio.2014.05.012>
- [22] Kjellenberg L, Johansson E, Gustavsson K-E, Olsson ME. Polyacetylenes in fresh and stored carrots (*Daucus carota*): relations to root morphology and sugar content. *Journal of the Science of Food and Agriculture*. 2012;92:1748-1754.10.1002/jsfa.5541

- [23] Eichholz I, Huyskens-Keil S, Rohn S. Chapter 21 - Blueberry Phenolic Compounds: Fruit Maturation, Ripening and Post-Harvest Effects. In: Preedy V, editor. *Processing and Impact on Active Components in Food*, <http://dx.doi.org/10.1016/B978-0-12-404699-3.00021-4>. San Diego: Academic Press; 2015. p. 173-180.
- [24] Caleb OJ, Mahajan PV, Manley M, Opara UL. Evaluation of parameters affecting modified atmosphere packaging engineering design for pomegranate arils. *International Journal of Food Science & Technology*. 2013;48:2315-2323. <http://doi.org/10.1111/ijfs.12220>
- [25] O'Grady L, Sigge G, Caleb OJ, Opara UL. Effects of storage temperature and duration on chemical properties, proximate composition and selected bioactive components of pomegranate (*Punica granatum* L.) arils. *LWT - Food Science and Technology*. 2014;57:508-515. <http://dx.doi.org/10.1016/j.lwt.2014.02.030>
- [26] Tano K, Oulé MK, Doyon G, Lencki RW, Arul J. Comparative evaluation of the effect of storage temperature fluctuation on modified atmosphere packages of selected fruit and vegetables. *Postharvest Biology and Technology*. 2007;46:212-221. <http://dx.doi.org/10.1016/j.postharvbio.2007.05.008>
- [27] Tietel Z, Lewinsohn E, Fallik E, Porat R. Importance of storage temperatures in maintaining flavor and quality of mandarins. *Postharvest Biology and Technology*. 2012;64:175-182. <http://dx.doi.org/10.1016/j.postharvbio.2011.07.009>
- [28] Watada AE, Ko NP, Minott DA. Factors affecting quality of fresh-cut horticultural products. *Postharvest Biology and Technology*. 1996;9:115-125. [http://dx.doi.org/10.1016/S0925-5214\(96\)00041-5](http://dx.doi.org/10.1016/S0925-5214(96)00041-5)
- [29] Carneiro G, Laferrère B, Zanella MT. Vitamin and mineral deficiency and glucose metabolism – A review. *e-SPEN Journal*. 2013;8:e73-e79. <http://dx.doi.org/10.1016/j.clnme.2013.03.003>
- [30] FAO. Vitamin and mineral requirements in human nutrition: report of a joint FAO/WHO expert consultation, Bangkok, Thailand, Second edition. 2001, <http://www.fao.org/3/a-y2809e.pdf>
- [31] Campbell I. Macronutrients, minerals, vitamins and energy. *Anaesthesia & Intensive Care Medicine*. 2014;15:344-349. <http://dx.doi.org/10.1016/j.mpaic.2014.04.003>
- [32] Wachter JM, Reganold JP. Organic Agricultural Production: Plants. In: Alfen NKV, editor. *Encyclopedia of Agriculture and Food Systems*; <http://dx.doi.org/10.1016/B978-0-444-52512-3.00159-5>. Oxford: Academic Press; 2014. p. 265-286.
- [33] Falguera V, Aliguer N, Falguera M. An integrated approach to current trends in food consumption: Moving toward functional and organic products? *Food Control*. 2012;26:274-281. <http://dx.doi.org/10.1016/j.foodcont.2012.01.051>
- [34] EU, Scientific Committee for Food. Opinion on nitrate and nitrite (expressed on 22 September 1995), Annex 4 to document III/56/95, CS/CNTM/NO3/20-FINAL.1995

http://ec.europa.eu/food/safety/docs/labelling_nutrition-special_groups_food-children-scf_reports_38_en.pdf

- [35] Moral R, Paredes C, Bustamante MA, Marhuenda-Egea F, Bernal MP. Utilisation of manure composts by high-value crops: Safety and environmental challenges. *Biore-source Technology*. 2009;100:5454-5460.<http://dx.doi.org/10.1016/j.biortech.2008.12.007>
- [36] Worthington V. Nutritional Quality of Organic Versus Conventional Fruits, Vegetables, and Grains. *The Journal of Alternative and Complementary Medicine*. 2001;7:161-173.[10.1089/107555301750164244](https://doi.org/10.1089/107555301750164244)
- [37] Ismail A FChnompmmnnap. Determination of vitamin C, β -carotene and riboflavin contents in five green vegetables organically and conventionally grown.. *Malaysian Journal of Nutrition*. 2003;9:31-39, http://nutriweb.org.my/publications/mjn009_1/mjn9n1_art4.pdf
- [38] Ryan MH, Derrick JW, Dann PR. Grain mineral concentrations and yield of wheat grown under organic and conventional management. *Journal of the Science of Food and Agriculture*. 2004;84:207-216.[10.1002/jsfa.1634](https://doi.org/10.1002/jsfa.1634)
- [39] Wszelaki AL, Delwiche JF, Walker SD, Liggett RE, Scheerens JC, Kleinhenz MD. Sensory quality and mineral and glycoalkaloid concentrations in organically and conventionally grown redskin potatoes (*Solanum tuberosum*). *Journal of the Science of Food and Agriculture*. 2005;85:720-726.[10.1002/jsfa.2051](https://doi.org/10.1002/jsfa.2051)
- [40] Mäder P, Hahn D, Dubois D, Gunst L, Alföldi T, Bergmann H, et al. Wheat quality in organic and conventional farming: results of a 21 year field experiment. *Journal of the Science of Food and Agriculture*. 2007;87:1826-1835.[10.1002/jsfa.2866](https://doi.org/10.1002/jsfa.2866)
- [41] Amodio ML, Colelli G, Hasey JK, Kader AA. A comparative study of composition and postharvest performance of organically and conventionally grown kiwifruits. *Journal of the Science of Food and Agriculture*. 2007;87:1228-1236.[10.1002/jsfa.2820](https://doi.org/10.1002/jsfa.2820)
- [42] Rossi F, Godani F, Bertuzzi T, Trevisan M, Ferrari F, Gatti S. Health-promoting substances and heavy metal content in tomatoes grown with different farming techniques. *European Journal of Nutrition*. 2008;47:266-272.[10.1007/s00394-008-0721-z](https://doi.org/10.1007/s00394-008-0721-z)
- [43] Wunderlich SM, Feldman C, Kane S, Hazhin T. Nutritional quality of organic, conventional, and seasonally grown broccoli using vitamin C as a marker. *International Journal of Food Sciences and Nutrition*. 2008;59:34-45.[10.1080/09637480701453637](https://doi.org/10.1080/09637480701453637)
- [44] Citak S, Sonmez S. Effects of conventional and organic fertilization on spinach (*Spinacea oleracea* L.) growth, yield, vitamin C and nitrate concentration during two successive seasons. *Scientia Horticulturae*. 2010;126:415-420.<http://dx.doi.org/10.1016/j.scienta.2010.08.010>

- [45] Kahu K, Jänes H, Luik A, Klaas L. Yield and fruit quality of organically cultivated blackcurrant cultivars. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*. 2008;59:63-69.[10.1080/09064710701865139](http://dx.doi.org/10.1080/09064710701865139)
- [46] Herencia JF, García-Galavís PA, Dorado JAR, Maqueda C. Comparison of nutritional quality of the crops grown in an organic and conventional fertilized soil. *Scientia Horticulturae*. 2011;129:882-888.<http://dx.doi.org/10.1016/j.scienta.2011.04.008>
- [47] Cardoso PC, Tomazini APB, Stringheta PC, Ribeiro SMR, Pinheiro-Sant'Ana HM. Vitamin C and carotenoids in organic and conventional fruits grown in Brazil. *Food Chemistry*. 2011;126:411-416.<http://dx.doi.org/10.1016/j.foodchem.2010.10.109>
- [48] Picchi V, Migliori C, Lo Scalzo R, Campanelli G, Ferrari V, Di Cesare LF. Phytochemical content in organic and conventionally grown Italian cauliflower. *Food Chemistry*. 2012;130:501-509.<http://dx.doi.org/10.1016/j.foodchem.2011.07.036>
- [49] Carillo P, Cacace D, De Pascale S, Rapacciuolo M, Fuggi A. Organic vs. traditional potato powder. *Food Chemistry*. 2012;133:1264-1273.<http://dx.doi.org/10.1016/j.foodchem.2011.08.088>
- [50] Crecente-Campo J, Nunes-Damaceno M, Romero-Rodríguez MA, Vázquez-Odériz ML. Color, anthocyanin pigment, ascorbic acid and total phenolic compound determination in organic versus conventional strawberries (*Fragaria* × *ananas* Duch, cv Selva). *Journal of Food Composition and Analysis*. 2012;28:23-30.<http://dx.doi.org/10.1016/j.jfca.2012.07.004>
- [51] Maggio A, De Pascale S, Paradiso R, Barbieri G. Quality and nutritional value of vegetables from organic and conventional farming. *Scientia Horticulturae*. 2013;164:532-539.<http://dx.doi.org/10.1016/j.scienta.2013.10.005>
- [52] López A, Fenoll J, Hellín P, Flores P. Physical characteristics and mineral composition of two pepper cultivars under organic, conventional and soilless cultivation. *Scientia Horticulturae*. 2013;150:259-266.<http://dx.doi.org/10.1016/j.scienta.2012.11.020>
- [53] Vinha AF, Barreira SVP, Costa ASG, Alves RC, Oliveira MBPP. Organic versus conventional tomatoes: Influence on physicochemical parameters, bioactive compounds and sensorial attributes. *Food and Chemical Toxicology*. 2014;67:139-144.<http://dx.doi.org/10.1016/j.fct.2014.02.018>
- [54] Raffo A, Baiamonte I, Bucci R, D'Aloise A, Kelderer M, Matteazzi A, et al. Effects of different organic and conventional fertilisers on flavour related quality attributes of cv. Golden Delicious apples. *LWT - Food Science and Technology*. 2014;59:964-972.<http://dx.doi.org/10.1016/j.lwt.2014.06.045>
- [55] Kang Y, Khan S, Ma X. Climate change impacts on crop yield, crop water productivity and food security – A review. *Progress in Natural Science*. 2009;19:1665-1674.<http://dx.doi.org/10.1016/j.pnsc.2009.08.001>

- [56] Dangour AD, Dodhia SK, Hayter A, Allen E, Lock K, Uauy R. Nutritional quality of organic foods: a systematic review. *The American Journal of Clinical Nutrition*. 2009;10.3945/ajcn.2009.28041.10.3945/ajcn.2009.28041
- [57] Conti S, Villari G, Faugno S, Melchionna G, Somma S, Caruso G. Effects of organic vs. conventional farming system on yield and quality of strawberry grown as an annual or biennial crop in southern Italy. *Scientia Horticulturae*. 2014;180:63-71.<http://dx.doi.org/10.1016/j.scienta.2014.10.015>
- [58] Gangolli SD, van den Brandt PA, Feron VJ, Janzowsky C, Koeman JH, Speijers GJA, et al. Nitrate, nitrite and N-nitroso compounds. *European Journal of Pharmacology: Environmental Toxicology and Pharmacology*. 1994;292:1-38.[http://dx.doi.org/10.1016/0926-6917\(94\)90022-1](http://dx.doi.org/10.1016/0926-6917(94)90022-1)
- [59] Correia M, Barroso Â, Barroso MF, Soares D, Oliveira MBPP, Delerue-Matos C. Contribution of different vegetable types to exogenous nitrate and nitrite exposure. *Food Chemistry*. 2010;120:960-966.<http://dx.doi.org/10.1016/j.foodchem.2009.11.030>
- [60] Savino F, Maccario S, Guidi C, Castagno E, Farinasso D, Cresi F, et al. Methemoglobinemia Caused by the Ingestion of Courgette Soup Given in Order to Resolve Constipation in Two Formula-Fed Infants. *Annals of Nutrition and Metabolism*. 2006;50:368-371, <http://www.karger.com/DOI/10.1159/000094301>
- [61] Guadagnin SG, Rath S, Reyes FGR. Evaluation of the nitrate content in leaf vegetables produced through different agricultural systems. *Food Additives & Contaminants*. 2005;22:1203-1208.10.1080/02652030500239649
- [62] González-Gallego J, García-Mediavilla MV, Sánchez-Campos S, Tuñón MJ. Fruit polyphenols, immunity and inflammation. *British Journal of Nutrition*. 2010;104:S15-S27.[doi:10.1017/S0007114510003910](http://dx.doi.org/10.1017/S0007114510003910)
- [63] Burns IG, Zhang K, Turner MK, Meacham M, Al-Redhiman K, Lynn J, et al. Screening for genotype and environment effects on nitrate accumulation in 24 species of young lettuce. *Journal of the Science of Food and Agriculture*. 2011;91:553-562.10.1002/jsfa.4220
- [64] Burns I, Durnford J, Lynn J, McClement S, Hand P, Pink D. The influence of genetic variation and nitrogen source on nitrate accumulation and iso-osmotic regulation by lettuce. *Plant and Soil*. 2012;352:321-339.10.1007/s11104-011-0999-0
- [65] Björkman M, Klingen I, Birch ANE, Bones AM, Bruce TJA, Johansen TJ, et al. Phytochemicals of Brassicaceae in plant protection and human health – Influences of climate, environment and agronomic practice. *Phytochemistry*. 2011;72:538-556.<http://dx.doi.org/10.1016/j.phytochem.2011.01.014>
- [66] Harborne JB. Recent advances in chemical ecology. *Natural Product Reports*. 1989;6:85-109.10.1039/NP9890600085

- [67] Liu RH, Finley J. Potential Cell Culture Models for Antioxidant Research. *Journal of Agricultural and Food Chemistry*. 2005;53:4311-4314.10.1021/jf058070i
- [68] Higdon JV, Delage B, Williams DE, Dashwood RH. Cruciferous vegetables and human cancer risk: epidemiologic evidence and mechanistic basis. *Pharmacological Research*. 2007;55:224-236.<http://dx.doi.org/10.1016/j.phrs.2007.01.009>
- [69] Fenwick GR, Heaney RK, Mullin WJ, VanEtten CH. Glucosinolates and their breakdown products in food and food plants. *C R C Critical Reviews in Food Science and Nutrition*. 1983;18:123-201.10.1080/10408398209527361
- [70] Melchini A, Costa C, Traka M, Miceli N, Mithen R, De Pasquale R, et al. Erucin, a new promising cancer chemopreventive agent from rocket salads, shows anti-proliferative activity on human lung carcinoma A549 cells. *Food and Chemical Toxicology*. 2009;47:1430-1436.<http://dx.doi.org/10.1016/j.fct.2009.03.024>
- [71] Zhang Y, Munday R, Jobson HE, Munday CM, Lister C, Wilson P, et al. Induction of GST and NQO1 in Cultured Bladder Cells and in the Urinary Bladders of Rats by an Extract of Broccoli (*Brassica oleracea italica*) Sprouts. *Journal of Agricultural and Food Chemistry*. 2006;54:9370-9376.10.1021/jf062109h
- [72] Edge R, McGarvey DJ, Truscott TG. The carotenoids as anti-oxidants — a review. *Journal of Photochemistry and Photobiology B: Biology*. 1997;41:189-200.[http://dx.doi.org/10.1016/S1011-1344\(97\)00092-4](http://dx.doi.org/10.1016/S1011-1344(97)00092-4)
- [73] Wright ME, Virtamo J, Hartman AM, Pietinen P, Edwards BK, Taylor PR, et al. Effects of α -tocopherol and β -carotene supplementation on upper aerodigestive tract cancers in a large, randomized controlled trial. *Cancer*. 2007;109:891-898.10.1002/cncr.22482
- [74] Tapiero H, Townsend DM, Tew KD. The role of carotenoids in the prevention of human pathologies. *Biomedicine & Pharmacotherapy*. 2004;58:100-110.<http://dx.doi.org/10.1016/j.biopha.2003.12.006>
- [75] Moeller SM, Volland R, Tinker L, et al. Associations between age-related nuclear cataract and lutein and zeaxanthin in the diet and serum in the carotenoids in the age-related eye disease study (carets), an ancillary study of the women's health initiative. *Archives of Ophthalmology*. 2008;126:354-364.10.1001/archophth.126.3.354
- [76] Trumbo PR, Ellwood KC. Lutein and zeaxanthin intakes and risk of age-related macular degeneration and cataracts: an evaluation using the Food and Drug Administration's evidence-based review system for health claims. *The American Journal of Clinical Nutrition*. 2006;84:971-974, <http://ajcn.nutrition.org/content/84/5/971.abstract>
- [77] Spencer JPE, Abd El Mohsen MM, Minihaane A-M, Mathers JC. Biomarkers of the intake of dietary polyphenols: strengths, limitations and application in nutrition research. *British Journal of Nutrition*. 2008;99:12-22. <http://dx.doi.org/10.1017/S0007114507798938>

- [78] Kondratyuk TP, Pezzuto JM. Natural Product Polyphenols of Relevance to Human Health. *Pharmaceutical Biology*. 2004;42:46-63.doi:10.3109/13880200490893519
- [79] Fernandes VC, Domingues VF, de Freitas V, Delerue-Matos C, Mateus N. Strawberries from integrated pest management and organic farming: Phenolic composition and antioxidant properties. *Food Chemistry*. 2012;134:1926-1931.<http://dx.doi.org/10.1016/j.foodchem.2012.03.130>
- [80] Vicas S, Teusdea A, Carbutar M, Socaci S, Socaciu C. Glucosinolates Profile and Antioxidant Capacity of Romanian Brassica Vegetables Obtained by Organic and Conventional Agricultural Practices. *Plant Foods for Human Nutrition*. 2013;68:313-321.10.1007/s11130-013-0367-8
- [81] Wang SY, Millner P. Effect of Different Cultural Systems on Antioxidant Capacity, Phenolic Content, and Fruit Quality of Strawberries (*Fragaria × aranassa* Duch.). *Journal of Agricultural and Food Chemistry*. 2009;57:9651-9657.10.1021/jf9020575
- [82] García-Mier L, Guevara-González R, Mondragón-Olguín V, del Rocío Verduzco-Cuellar B, Torres-Pacheco I. Agriculture and Bioactives: Achieving Both Crop Yield and Phytochemicals. *International Journal of Molecular Sciences*. 2013;14:4203, <http://www.mdpi.com/1422-0067/14/2/4203>
- [83] Smith-Spangler C, Brandeau ML, Hunter GE, Bavinger JC, Pearson M, Eschbach PJ, et al. Are Organic Foods Safer or Healthier Than Conventional Alternatives?A Systematic Review. *Annals of Internal Medicine*. 2012;157:348-366.10.7326/0003-4819-157-5-201209040-00007
- [84] Oh M-M, Carey EE, Rajashekar CB. Environmental stresses induce health-promoting phytochemicals in lettuce. *Plant Physiology and Biochemistry*. 2009;47:578-583.<http://dx.doi.org/10.1016/j.plaphy.2009.02.008>
- [85] Lv J, Lu Y, Niu Y, Whent M, Ramadan MF, Costa J, et al. Effect of genotype, environment, and their interaction on phytochemical compositions and antioxidant properties of soft winter wheat flour. *Food Chemistry*. 2013;138:454-462.<http://dx.doi.org/10.1016/j.foodchem.2012.10.069>
- [86] Weibel FP TD, Haseli A, Graf U. Sensory and health related quality of organic apples: a comparative field study over three years using conventional and holistic methods to assess fruit quality. 1th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit Growing; LVWO: Weinsberg, Germany. 2004, 8 pp. <http://orgprints.org/14536/>
- [87] Ren H, Endo H, Hayashi T. Antioxidative and antimutagenic activities and polyphenol content of pesticide-free and organically cultivated green vegetables using water-soluble chitosan as a soil modifier and leaf surface spray. *Journal of the Science of Food and Agriculture*. 2001;81:1426-1432.10.1002/jsfa.955
- [88] Carbonaro M, Mattera M, Nicoli S, Bergamo P, Cappelloni M. Modulation of Antioxidant Compounds in Organic vs Conventional Fruit (Peach, *Prunus persica* L., and

- Pear, *Pyrus communis* L.). *Journal of Agricultural and Food Chemistry*. 2002;50:5458-5462.10.1021/jf0202584
- [89] Lombardi-Boccia G, Lucarini M, Lanzi S, Aguzzi A, Cappelloni M. Nutrients and Antioxidant Molecules in Yellow Plums (*Prunus domestica* L.) from Conventional and Organic Productions: A Comparative Study. *Journal of Agricultural and Food Chemistry*. 2004;52:90-94.10.1021/jf0344690
- [90] Asami DK, Hong Y-J, Barrett DM, Mitchell AE. Comparison of the Total Phenolic and Ascorbic Acid Content of Freeze-Dried and Air-Dried Marionberry, Strawberry, and Corn Grown Using Conventional, Organic, and Sustainable Agricultural Practices. *Journal of Agricultural and Food Chemistry*. 2003;51:1237-1241.10.1021/jf020635c
- [91] Caris-Veyrat C, Amiot M-J, Tyssandier V, Grasselly D, Buret M, Mikolajczak M, et al. Influence of Organic versus Conventional Agricultural Practice on the Antioxidant Microconstituent Content of Tomatoes and Derived Purees; Consequences on Antioxidant Plasma Status in Humans. *Journal of Agricultural and Food Chemistry*. 2004;52:6503-6509.10.1021/jf0346861
- [92] Robbins RJ, Keck A-S, Banuelos G, Finley JW. Cultivation Conditions and Selenium Fertilization Alter the Phenolic Profile, Glucosinolate, and Sulforaphane Content of Broccoli. *Journal of Medicinal Food*. 2005;8:204-214.10.1089/jmf.2005.8.204
- [93] Anttonen MJ, Hoppula KI, Nestby R, Verheul MJ, Karjalainen RO. Influence of Fertilization, Mulch Color, Early Forcing, Fruit Order, Planting Date, Shading, Growing Environment, and Genotype on the Contents of Selected Phenolics in Strawberry (*Fragaria × ananassa* Duch.) Fruits. *Journal of Agricultural and Food Chemistry*. 2006;54:2614-2620.10.1021/jf052947w
- [94] Perkins-Veazie P, Roberts W, Collins JK. Lycopene Content Among Organically Produced Tomatoes. *Journal of Vegetable Science*. 2007;12:93-106.10.1300/J484v12n04_07
- [95] Barrett DM, Weakley C, Diaz JV, Watnik M. Qualitative and Nutritional Differences in Processing Tomatoes Grown under Commercial Organic and Conventional Production Systems. *Journal of Food Science*. 2007;72:C441-C451.10.1111/j.1750-3841.2007.00500.x
- [96] Wang SY, Chen C-T, Sciarappa W, Wang CY, Camp MJ. Fruit Quality, Antioxidant Capacity, and Flavonoid Content of Organically and Conventionally Grown Blueberries. *Journal of Agricultural and Food Chemistry*. 2008;56:5788-5794.10.1021/jf703775r
- [97] Stracke BA, Rüfer CE, Weibel FP, Bub A, Watzl B. Three-Year Comparison of the Polyphenol Contents and Antioxidant Capacities in Organically and Conventionally Produced Apples (*Malus domestica* Bork. Cultivar 'Golden Delicious'). *Journal of Agricultural and Food Chemistry*. 2009;57:4598-4605.10.1021/jf803961f
- [98] Luthria D, Singh AP, Wilson T, Vorsa N, Banuelos GS, Vinyard BT. Influence of conventional and organic agricultural practices on the phenolic content in eggplant pulp:

- Plant-to-plant variation. *Food Chemistry*. 2010;121:406-411.<http://dx.doi.org/10.1016/j.foodchem.2009.12.055>
- [99] Balisteiro DM, Rombaldi CV, Genovese MI. Protein, isoflavones, trypsin inhibitory and in vitro antioxidant capacities: Comparison among conventionally and organically grown soybeans. *Food Research International*. 2013;51:8-14.<http://dx.doi.org/10.1016/j.foodres.2012.11.015>
- [100] Miranda Rossetto MR, Shiga TM, Vianello F, Pereira Lima GP. Analysis of total glucosinolates and chromatographically purified benzylglucosinolate in organic and conventional vegetables. *LWT - Food Science and Technology*. 2013;50:247-252.<http://dx.doi.org/10.1016/j.lwt.2012.05.022>
- [101] López A, Fenoll J, Hellín P, Flores P. Cultivation approach for comparing the nutritional quality of two pepper cultivars grown under different agricultural regimes. *LWT - Food Science and Technology*. 2014;58:299-305.<http://dx.doi.org/10.1016/j.lwt.2014.02.048>
- [102] Valverde J, Reilly K, Villacreces S, Gaffney M, Grant J, Brunton N. Variation in bioactive content in broccoli (*Brassica oleracea* var. *italica*) grown under conventional and organic production systems. *Journal of the Science of Food and Agriculture*. 2015;95:1163-1171.[10.1002/jsfa.6804](http://dx.doi.org/10.1002/jsfa.6804)
- [103] Migliori C, Di Cesare LF, Lo Scalzo R, Campanelli G, Ferrari V. Effects of organic farming and genotype on alimentary and nutraceutical parameters in tomato fruits. *Journal of the Science of Food and Agriculture*. 2012;92:2833-2839.[10.1002/jsfa.5602](http://dx.doi.org/10.1002/jsfa.5602)
- [104] Del Rio D, Rodriguez-Mateos A, Spencer JPE, Tognolini M, Borges G, Crozier A. Dietary (Poly)phenolics in Human Health: Structures, Bioavailability, and Evidence of Protective Effects Against Chronic Diseases. *Antioxidants & Redox Signaling*. 2012;18:1818-1892.[10.1089/ars.2012.4581](http://dx.doi.org/10.1089/ars.2012.4581)
- [105] Stan SD, Kar S, Stoner GD, Singh SV. Bioactive food components and cancer risk reduction. *Journal of Cellular Biochemistry*. 2008;104:339-356.[10.1002/jcb.21623](http://dx.doi.org/10.1002/jcb.21623)
- [106] Vincent HK, Bourguignon CM, Taylor AG. Relationship of the dietary phytochemical index to weight gain, oxidative stress and inflammation in overweight young adults. *Journal of Human Nutrition and Dietetics*. 2010;23:20-29.[10.1111/j.1365-277X.2009.00987.x](http://dx.doi.org/10.1111/j.1365-277X.2009.00987.x)
- [107] Garaguso I, Nardini M. Polyphenols content, phenolics profile and antioxidant activity of organic red wines produced without sulfur dioxide/sulfites addition in comparison to conventional red wines. *Food Chemistry*. 2015;179:336-342.<http://dx.doi.org/10.1016/j.foodchem.2015.01.144>
- [108] Unal K SD, Taher M. Polyphenol content and antioxidant capacity in organically and conventionally grown vegetables. *Journal of Coastal Life Medicine*. 2014;2:864-871, <http://www.jclmm.com/qk/201411/6.pdf>

- [109] Straus S BF, Turinek M, Slatnar A, Rozman C, Bavec M. Nutritional value and economic feasibility of red beetroot (*Beta vulgaris* L. ssp. *vulgaris* Rote Kugel) from different production systems. *African Journal of Agricultural Research*. 2012;7:5653–5660, http://www.oxfordjournals.jurnalpedia.academicjournals.org/article/article1380984270_Straus%20et%20al.pdf
- [110] Oliveira AB MC, Gomes-Filho E, Marco CA, Urban L, Miranda MRA. The Impact of Organic Farming on Quality of Tomatoes Is Associated to Increased Oxidative Stress during Fruit Development. *Plos One*. 2013;8.10.1371/journal.pone.0056354
- [111] Lamperi L, Chiuminatto U, Cincinelli A, Galvan P, Giordani E, Lepri L, et al. Polyphenol Levels and Free Radical Scavenging Activities of Four Apple Cultivars from Integrated and Organic Farming in Different Italian Areas. *Journal of Agricultural and Food Chemistry*. 2008;56:6536-6546.10.1021/jf801378m
- [112] Faller ALK, Fialho E. From the market to the plate: Fate of bioactive compounds during the production of feijoada meal and the impact on antioxidant capacity. *Food Research International*. 2012;49:508-515.<http://dx.doi.org/10.1016/j.foodres.2012.08.008>
- [113] Aldrich HT, Salandanan K, Kendall P, Bunning M, Stonaker F, Külen O, et al. Cultivar choice provides options for local production of organic and conventionally produced tomatoes with higher quality and antioxidant content. *Journal of the Science of Food and Agriculture*. 2010;90:2548-2555.10.1002/jsfa.4116
- [114] Mulero J, Pardo F, Zafrilla P. Antioxidant activity and phenolic composition of organic and conventional grapes and wines. *Journal of Food Composition and Analysis*. 2010;23:569-574.<http://dx.doi.org/10.1016/j.jfca.2010.05.001>
- [115] Heimler D, Vignolini P, Arfaioli P, Isolani L, Romani A. Conventional, organic and biodynamic farming: differences in polyphenol content and antioxidant activity of Batavia lettuce. *Journal of the Science of Food and Agriculture*. 2012;92:551-556.10.1002/jsfa.4605
- [116] Borguini RG, Bastos DHM, Moita-Neto JM, Capasso FS, Torres EAFdS. Antioxidant potential of tomatoes cultivated in organic and conventional systems. *Brazilian Archives of Biology and Technology*. 2013;56:521-529, http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-89132013000400001&nrm=iso
- [117] Navarro P, Pérez-López AJ, Mercader MT, Carbonell-Barrachina AA, Gabaldon JA. Antioxidant Activity, Color, Carotenoids Composition, Minerals, Vitamin C and Sensory Quality of Organic and Conventional Mandarin Juice, cv. Orogrande. *Food Science and Technology International*. 2011;17:241-248.10.1177/1082013210382334
- [118] Roitner-Schobesberger B, Darnhofer I, Somsook S, Vogl CR. Consumer perceptions of organic foods in Bangkok, Thailand. *Food Policy*. 2008;33:112-121.<http://dx.doi.org/10.1016/j.foodpol.2007.09.004>

- [119] Cerjak M, Mesić Ž, Kopic M, Kovačić D, Markovina J. What Motivates Consumers to Buy Organic Food: Comparison of Croatia, Bosnia Herzegovina, and Slovenia. *Journal of Food Products Marketing*. 2010;16:278-292.10.1080/10454446.2010.484745
- [120] Ozguven N. Organic Foods Motivations Factors for Consumers. *Procedia - Social and Behavioral Sciences*. 2012;62:661-665.<http://dx.doi.org/10.1016/j.sbspro.2012.09.110>
- [121] Ballute AK BP. The perceptions of and motivations for purchase of organic and local foods. *Journal of Contemporary Issues in Business Research*. 2014;3:1-18, <http://jcibr.webs.com/Archives/Volume-2014/Issue-1-january/Article-V-3-N-1-082013JCIBR0037.pdf>
- [122] Henryks J PD. Investigating the context of purchase choices to further understanding of switching behaviour. *Journal of Organic Systems*. 2014;9:38-48, http://www.organic-systems.org/journal/92/JOS_Volume-9_Number-2_Nov-2014_Henryks-&-Pearson.pdf
- [123] Stanton JV, Guion DT. Perceptions of “Organic” Food: A View Through Brand Theory. *Journal of International Food & Agribusiness Marketing*. 2015;27:120-141.10.1080/08974438.2014.897667
- [124] Cicia G DGT, Ramunno I, Tagliaferro C. Splitting Consumer’s Willingness to Pay Premium Price for Organic Products over Purchase Motivations. 98th Seminar of the European Association of Agricultural Economics (EAAE) Marketing Dynamics within the Global Trading System: New Perspectives, Chania, Crete, Greece, June 29 - July 2. 2006, http://www.researchgate.net/profile/Pietro_Pulina/publication/28685241_The_Motivational_Profile_of_Organic_Food_Consumers_a_Survey_of_SpecializedStores_Customers_in_Italy/links/00b7d52dfdeef516f5000000.pdf
- [125] Monk A M, B, Lobo A, Chen J, Bez N. Australian organic market report 2012. Brisbane: Biological Farmers Association (BFA) Ltd. 2012, 100 pp. <http://austorganic.com/wp-content/uploads/2013/09/Organic-market-report-2012-web.pdf>
- [126] McCarthy B, Murphy L. Who s buying organic food and why?: Political consumerism, demographic characteristics and motivations of consumers in North Queensland. *Tourism & Management Studies*. 2013;9:72-79, http://www.scielo.mec.pt/scielo.php?script=sci_arttext&pid=S2182-84582013000100011&nrm=iso
- [127] H I. Consumers’ Attitude and Intention towards Organic Food Purchase: An Extension of Theory of Planned Behaviour in Gender Perspective. *International Journal of Management, Economics and Social Sciences*. 2015;4:17 – 31, <http://ssrn.com/abstract=2578399>